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Effects of Dietary Modification on Laying Hens in High-rise Houses: Part I –Ammonia, Hydrogen Sulfide and Carbon Dioxide Emissions

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Summary and Implications

Dietary manipulation can substantially lower ammonia (NH_3) emissions from laying-hen houses or manure storage. Recent lab studies showed a NH_3 emission reduction of 40–60% for an experimental (EcoCal^{TM}) diet as compared to the standard or control diet. The study reported here was a field verification test about the effects of EcoCal diet on NH_3, hydrogen sulfide (H_2S) and carbon dioxide (CO_2) emissions, hen production performance, and the economic returns for a commercial high-rise layer operation in Iowa. Comparative data were collected during December 2006 to May 2007. The results showed that the EcoCal diet led to NH_3 emission reduction by up to 23.2% (0.86±0.04 vs. 1.12±0.03 g NH_3 d^{-1} hen^{-1} for EcoCal vs. Control diet, respectively) while H_2S emission increased by up to 134% (4.38±0.20 vs. 1.82±0.07 mg d^{-1} hen^{-1} for EcoCal vs. Control, respectively). However, H_2S emissions were small for both dietary regimens.

Introduction

Ammonia (NH_3) emissions from animal feeding operations (AFO) have been estimated to represent the largest portion of the national NH_3 emissions inventory in the United States. To improve the environmental stewardship and indoor air quality, the egg industry has been progressively looking for practical means to reduce NH_3 generation and/or emissions from the production facilities. Ammonia is mainly released from uric acid of bird feces. Reducing manure pH value can reduce or prevent NH_3 volatilization. Zeolite and gypsum ($CaSO_4$) feed additives can be incorporated to bird diet to sequester or trap NH_3 and result in acidic manure, thereby causing NH_3 to be converted to NH_4^+.

The objective of this field study was to evaluate the effects of feeding laying hens diet containing EcoCal (3.5% by weight) on NH_3, H_2S, and CO_2 emissions, production performance, and the economic returns for a commercial high-rise layer operation in Iowa. This paper reports the effects of the diet on gaseous emissions.

Materials and Methods

This study involved two commercial high-rise layer houses in central Iowa, each measuring 27.4 m × 180.4 m (90 × 592 ft). One house with approximately 256,000 Hy-Line W-36 hens was fed the EcoCal diet (EcoCal) while the other with approximately 262,000 Hy-Line W-36 hens was fed the control diet (Control). On November 23, 2006, hens (79 wk of age) in the EcoCal house began to receive a diet containing 1.75% EcoCal, while hens (87 wk of age) in the Control house continued to be fed the Control (EcoCal-free) diet. Stocking density was 432 cm^2 or 67 in^2 per hen in both houses. On November 30, 2006, addition of EcoCal was increased to 3.5%. On May 20, 2007, the Control hens were replaced with a new flock, which marked the end of the dietary comparison. A mobile air emissions monitoring unit (MAEMU) housing the measurement and data acquisition systems was used to continuously collect data on NH_3, H_2S and CO_2 emissions from both hen houses. A photoacoustic multi-gas analyzer (INNOVA model 1412) was used to measure NH_3 and CO_2 concentrations and dew-point temperature; and a UV fluorescence analyzer (Teledyne, API Model 101E) was used to measure H_2S concentrations. Air samples were drawn from three composite locations (east, middle, and west parts) in each house as well as from an outside location to provide ambient background data. Ventilation rate of each house was measured continuously.

The data were collected for 175 d from December 1, 2006 to May 20, 2007. Due to instrumentation problems and routine calibration and power outage, 11 days data were missing and a total of 164-d data were available and used in the data analysis. Statistical analysis was performed using JMP (version 6.0, SAS Institute, Inc., Cary, NC). Data were analyzed using ANOVA and each week was considered as a repeated measure during the monitoring period. The dietary effect was considered significant at P-values ≤ 0.05.

Results and Discussion

The NH_3, H_2S, and CO_2 emission rates (ERs) for the EcoCal and Control houses were plotted in Figure 5. Daily mean (± standard error) NH_3 ER for the EcoCal and Control houses over the 175-d period was 0.86±0.04 and 1.12±0.03 g d^{-1} hen^{-1}, respectively ($P<0.001$; Table 1) an overall NH_3 ER reduction of 23.2%by the EcoCal diet. The daily NH_3 ER of the current study was comparable to the annual mean NH_3 ER of 0.90±0.03 g d^{-1} hen^{-1} for high-rise layer houses in Iowa fed a standard diet, as reported by Liang et al. (2006). Daily mean CO_2 ER for the EcoCal and Control houses during the same period was 95.0±1.7 and 99.1±2.1 g

d^{-1} hen^{-1}, respectively (P=0.017), although the difference was only 4%. The concomitant daily mean H_2S ER for the EcoCal and Control regimens was 4.38±0.20 and 1.82±0.07 mg d^{-1} hen^{-1}, respectively (P<0.001).
. The weekly H_2S ER increase varied from 96.5% to 231% and the monthly H_2S emission increase was in the range of 105% to 176% (Figure 1). In general, the H_2S increase rate increased with increasing outside temperature (P=0.005). The efficacy of NH_3 emission reduction by the EcoCal diet tended to decrease with time, which coincided with increasing outside temperature (P<0.001). As shown by the data in Figure 2, weekly NH_3 ER reduction varied from 3.3% to 48.2% and monthly NH_3 emission reduction ranged from 7.7% for May 2007 to 39.2% for February 2007. The seasonal variation in the dietary efficacy could have stemmed from changes in manure properties, particularly manure moisture content, as the weather condition and ventilation rate varied throughout the season. This outcome will be further examined with an ongoing demonstration about the effects of three dietary regimens, including EcoCal diet, applied to three commercial high-rise layer houses in Iowa.

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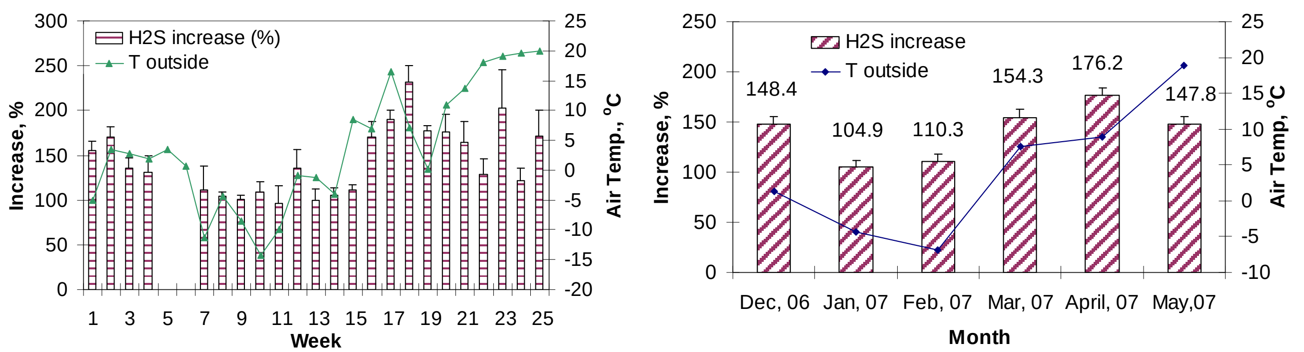

Figure 1. Weekly and monthly H_2S reduction from the EcoCal house and outside temperature.

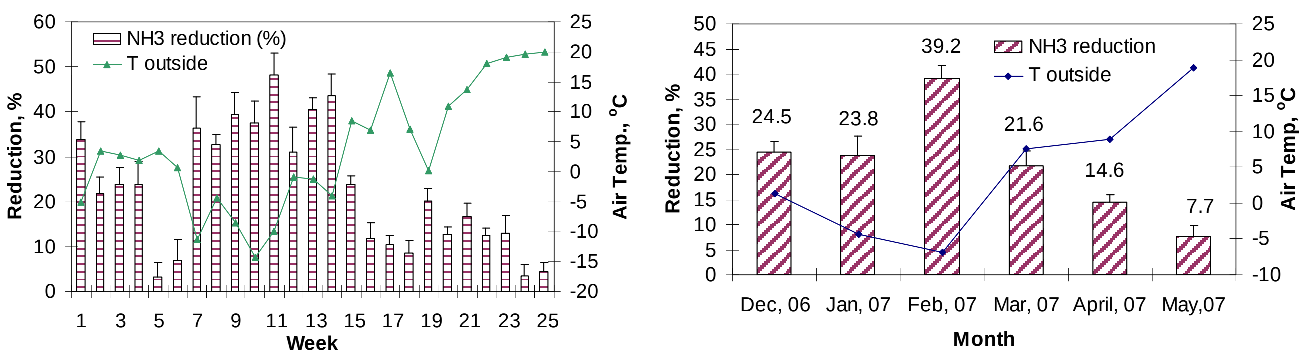

Figure 2. Weekly and monthly NH_3 reduction from the EcoCal house and outside temperature.

Table 1. Summary of gaseous emission rate (mean ± standard error) from the two high-rise layer houses fed different diets over 175-d testing period (December 2006 – May 2007)

Diet	T_{out}, °C	VR, m^3 hr^{-1} hen^{-1}	NH_3, g d^{-1} hen^{-1}	H_2S, mg d^{-1} hen^{-1}	CO_2, g d^{-1} hen^{-1}
EcoCal	3.6±1.6	1.61±0.20	0.86±0.04 ^{b}	4.38±0.20 ^{a}	95.0±1.7 ^{b}
Control		1.64±0.19	1.12±0.03 ^{a}	1.82±0.07 ^{b}	99.1±2.1^a

VR = ventilation rate of the layer house
Emission rates of each gas followed by different superscript letters are significantly different (P<0.05).